Simulated CO_2-Induced Changes in Tropical Climate and Variability

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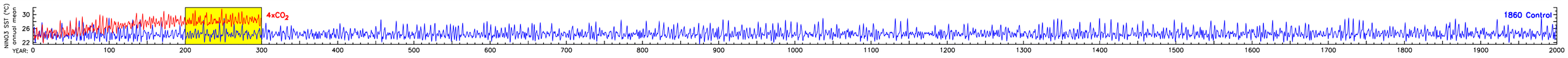
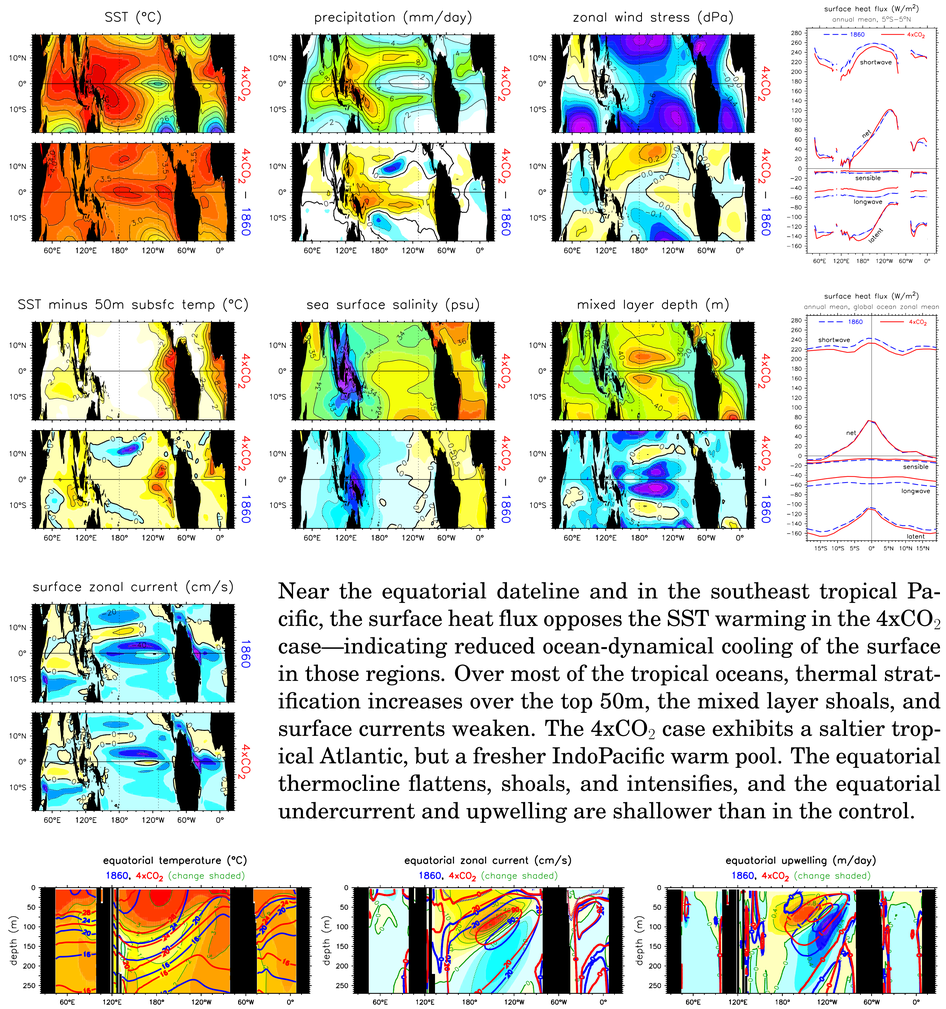


1. Introduction

We assess possible impacts of increased atmospheric CO_2 on tropical climate, using the CM2.1 global coupled climate model recently developed at NOAA/GFDL (Delworth et al. and Wittenberg et al., *J. Climate*, 2006). We compare a 2000yr pre-industrial control run (with fixed 1860 values of trace gases, aerosols, insolation, land cover, and 286ppmv CO_2) to a run in which CO_2 increases 1%/yr and then stabilizes at 4xCO_2 (1144ppmv) after year 140. We focus here on years 200–300, highlighted above.

2. Annual-Mean Changes

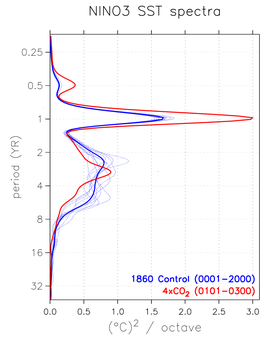
The 4xCO_2 simulation shows a fairly uniform 3–4°C warming of tropical SST. Rainfall and surface wind convergence increase along and just south of the equator, but decrease in the northern ITCZ. In the equatorial Pacific there is a slight weakening of the zonal SST contrast and surface easterly wind stress, and the trade winds become more symmetric about the equator. After CO_2 stabilization at 4x, the reduced annual-mean longwave cooling of the surface is compensated by increased evaporative cooling and reduced shortwave heating.

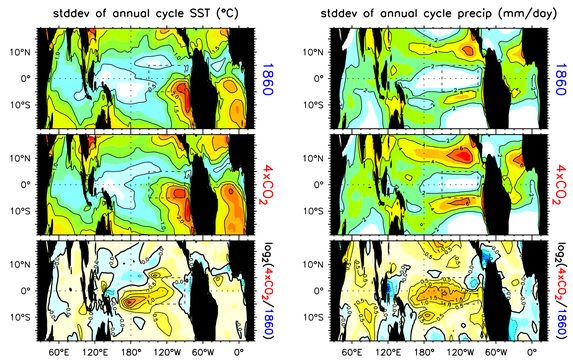


Near the equatorial dateline and in the southeast tropical Pacific, the surface heat flux opposes the SST warming in the 4xCO_2 case—indicating reduced ocean-dynamical cooling of the surface in those regions. Over most of the tropical oceans, thermal stratification increases over the top 50m, the mixed layer shoals, and surface currents weaken. The 4xCO_2 case exhibits a saltier tropical Atlantic, but a fresher IndoPacific warm pool. The equatorial thermocline flattens, shoals, and intensifies, and the equatorial undercurrent and upwelling are shallower than in the control.

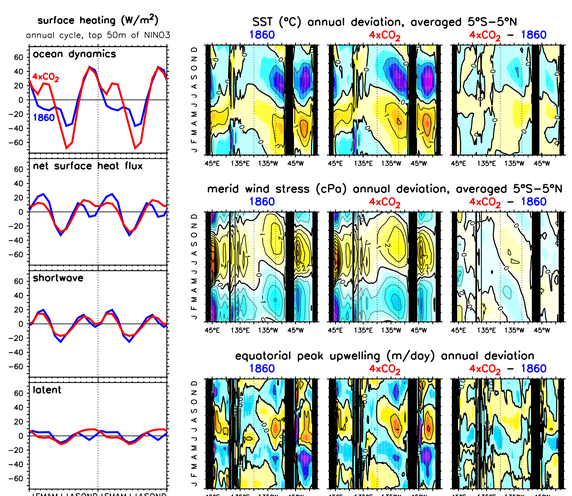
3. Seasonal Cycle Changes

The 4xCO_2 case shows an enhanced seasonal cycle of SST over the equatorial central Pacific, Atlantic, and eastern Indian Ocean. Seasonal rainfall variations are also enhanced over the equatorial Pacific, the Atlantic and Pacific ITCZs, and the Indian Ocean. In the eastern equatorial Pacific, the boreal spring peak & autumn nadir SST occur 2–4 weeks later than in the control.





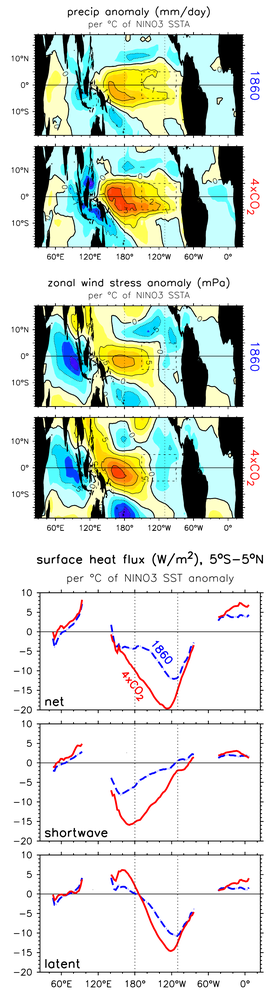
Changes in the NINO3 SST annual cycle are driven by a stronger cycle of ocean-dynamical cooling, and are slightly opposed by changes in the surface heat fluxes. Stronger southeasterly trade winds enhance the boreal summer/fall upwelling peak, while reduced trades amplify the boreal spring upwelling minimum.



4. Interannual Variability and ENSO

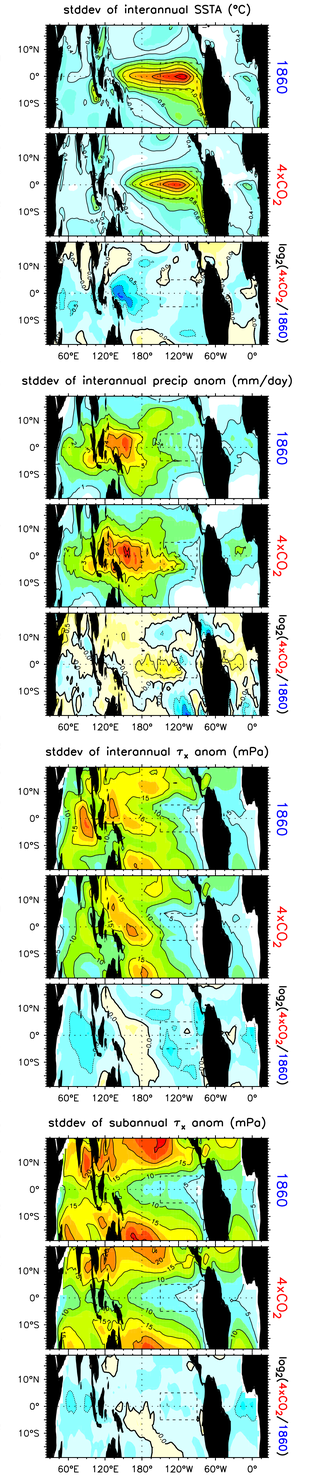
The 4xCO_2 case shows slightly weaker ENSO SST anomalies and a narrower ENSO spectrum. Given the strong multi-decadal modulation of ENSO in CM2.1, the changes in NINO3 SSTA spectra are detectable only with long time series. For shorter records, the larger fractional changes west of the dateline are more detectable than those in the east.

The 4xCO_2 case shows a zonal narrowing of Pacific ENSO SST variability, with weaker SSTAs near Indonesia and South America. The Indian Ocean and parts of the Atlantic also show weaker interannual SSTAs. In contrast, there is a strengthening and eastward shift of El Niño rainfall over the western and central equatorial Pacific. Zonal wind stress anomalies also increase near the dateline.



Initially it is surprising that ENSO SSTA variability *decreases* at 4xCO_2, given the *increased* sensitivity of the equatorial west/central Pacific precipitation and zonal wind stress to SSTAs. However, the surface heat flux damping of SST anomalies is also stronger at 4xCO_2—due to substantially increased cloud shading (in the central Pacific) and evaporation (in the east Pacific) during ENSO warm events.

Over the Indian Ocean, Atlantic, and east Pacific, the variability of zonal wind stress in the 4xCO_2 case weakens at both interannual and subannual time scales. However, the 4xCO_2 case also shows amplified El Niño heat flux forcing of the Indian and Atlantic oceans, with enhanced solar heating over both basins, and stronger reductions in evaporation over the Atlantic.



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